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Behavioural ecology of mango leaf webber, *Orthaga exvinacea* Hampson

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ABSTRACT: Behavioural studies of mango leaf webber, *Orthaga exvinacea* were carried out both in the laboratory and field conditions, majorly focusing on neaonate larva, mating, oviposition and intra specific competition. The feeding behaviour of *O. exvinacea* was found to be gregarious *i.e.,* a group of larvae coalesce together and scrape the chlorophyll content of young leaves. However, the later instars start feeding voraciously by making webs joining the adjacent leaves along with the shoots. The female moths laid eggs individually or in groups (8-14 eggs/cluster) on the lower surface of leaves near the midrib, while eggs were occasionally laid on the upper surface of the leaves during the early hours of photophase. Under field conditions, a series of observations revealed that the eggs were commonly laid in well-established older webs. During scotophase, several behavioural transitions in both male and female moths were observed while studying the mating behavior under laboratory conditions. Larval migration among the brood members of *O. exvinacea* was also noticed during the study.

Keywords: *Orthaga exvinacea*, mango, behavioural ecology, mating behavior, photophase, scotophase, brood members

INTRODUCTION

Mango leaf webber, *Orthaga exvinacea* Hampson (Pyralidae: Lepidoptera) is one of the important leaf-feeding insect pests in mango (*Mangifera indica* L.) responsible for low productivity (Reddy *et al*., 2013; Jayanthi *et al*., 2020). Though it was considered a minor pest earlier, in the recent past it has gained importance in all mango-growing locations and it has become a major pest in intensively farmed areas on both young and old plants a like (Srivastava and Verghese, 1983; Srivastava, 1997). *O. exvinacea* becomes a serious pest in extensively cropped areas of Uttar Pradesh, Uttaranchal, and Andhra Pradesh (Singh *et al*., 2006). *O. exvinacea* is responsible to cause ~35 percent yield loss under favourable environmental conditions (Tandon and Srivastava, 1982). The infestation of leaf webber begins in June and lasts until December. The caterpillars start webbing the leaves and feed on the entire leaf, leaving the midribs and veins. The heavily infested trees have a burnt appearance from distance, and significant levels of leaf webber infestation results in partial to complete failure of flower emergence (Verghese, 1998; Kavitha *et al*., 2005). Ninety percent of the defoliated/skeletonised branches dried and did not fruit in the next season due to webber infestation (Singh, 1988). *O. exvinacea* is responsible to cause ~35 percent yield loss under favourable environmental conditions (Tandon and Srivastava, 1982).

MATERIAL AND METHODS

Maintenance of test insects and host plants

Mango webber, *Orthaga exvinacea*

The cultures of target insect pest, *O. exvinacea* were established in the laboratory for continuous supply throughout the study period. The webs consisting of larvae, *O. exvinacea* were collected from the experimental fields of IIHR to establish initial culture. For this, mango plants were thoroughly searched for any webber infestation and the active webs with live larvae were identified. The active webs were carefully cut using secateurs and gently placed into a polythene cover (40 cm length x 30 cm width) and tied with rubber bungs to avoid any escape of larvae. The polythene covers containing webs were brought to the laboratory and the webs were transferred to insect cages (54 x 50 x 45 cm) carefully. These insect cages were placed at ambient conditions (27 ± 1^{o}C, 75±2% RH and 14L: 10D) and provided with fresh host plant (*Mangifera indica* L.) leaves on a daily basis until pupation. The pupae were collected when they formed and sexing was done by examining the location of genital slit in relation to anal slit (Khosravi and Sendi, 2010) under stereo microscope (Leica M205A). After sexing, the male and female pupae were placed in separate cages (30 x 30 x 30 cm) until adult emergence. The freshly emerged moths were provided with sugar /honey solution as food. These virgin insects were used for further studies on mating behaviour. To establish mated population, the freshly emerged male and female moths were released in to a cage (30 x 30 x 30 cm) and allowed to mate for 24 h.

Host plants

The host plants of target insect pest *i.e*., mango (*M. indica*) were maintained continuously under glass house conditions for experimental use. Two to three years old mango grafts (cv. Banganpalli) were obtained from the Nursery Unit of ICAR-IIHR, Bengaluru and were planted in the pots (27 cm height x 30 cm diam.) containing red soil and farm yard manure (in 1:1 ratio). All the standard agronomic practices were followed without any insecticidal sprays. The field collected larvae, *O. exvinacea* (2-3 larvae/plant) were released on mango potted plants to create the webber infestation and these infested mango plants were used for all further studies.

Oviposition behaviour

To observe the oviposition behaviour of *O. exvinacea,* individual healthy mango plants were kept in a net cage (1 x 1 x 1 m) under glass house conditions at Division of Plant Protection, ICAR-IIHR and exposed to gravid female moths. A total of five one day old gravid female moths (n = 5) from the above established insect culture was released in to each net cage. The host plants were exposed to gravid female moths continuously for 24h and observations were made on egg laying behaviour and egg hatching time with the help of magnified hand lens.

Behaviour of neonate larvae

The behaviour of neonate larvae was observed in the early photophase with the help of magnified lens and torch light on mango webber infested plants. The neonate larvae emerged from the eggs (laid by moths in the above experiment) were observed closely on potted mango plants under glass house conditions. Observations were made on feeding behaviour, time taken for webbing, larval migration to form separate webs, behaviour while pupation and identification of pupation site.

Mating behaviour

Mating behaviour of *O. exvinacea* was studied by releasing freshly emerged male and female moths in to a square glass mating chamber (30 x 30 x 30 x 30 cm). The mating chamber containing moths was placed in darkness and observations were made with the help of torch light covered with red colour cellophane tape to avoid any photo disturbance to moths. To understand the mating behaviour pattern, the observations were recorded during the early scotophase (6.00 PM) to early photophase (6.00 AM), when moths were active. Observations were recorded for every 10 min interval. A total of 30 mating episodes were observed. The different behavioural events (resting period (R), swift antennal movements (SAM), walking with antennal swift movement (WK), flight and fluttering of the wings (FL), mate tracking (MT), mate approaching (MA) and mating (M) were noticed in both male and female moths. All the behavioural observations were compiled across the episodes and mating behavioural ethogram was developed. Behavioural transitions were also calculated and analysed by first order markov model.

Intraspecific competition

Intraspecific larval competition within the web between the brood members of *O. exvinacea* was studied in the experimental orchards of Division of Fruit Crops, IIHR, Bengaluru. A total of 25 webs were tagged randomly on webber infested mango plants (cv. Arka Udaya). Each individual web was thoroughly examined initially for the presence of different life stages of *O. exvinacea* namely egg, larval instars and pupa with the help of magnified hand lens.

RESULTS AND DISCUSSION

Egg laying behaviour/ Oviposition

The egg-laying behaviour was studied under glasshouse conditions. Freshly emerged male and female *O. exvinacea* moths were collected from the above-established culture and allowed for mating in insect cages (30×30×30 cm) for 24 hr. Potted healthy mango plants were placed in a net cage (1 x 1 x 1 m) and post-mating, the female moths (n = 5) were released onto the above-potted mango plants to study the gravid female moth egg-laying behaviour. The female moths of *O. exvinacea* laid eggs singly as well as in groups (8-14 eggs/cluster) on the lower surface of leaves near the midrib and occasionally eggs were also laid on the upper surface of the leaves during the early hours (4.00 to 6.00 AM) of photophase. The freshly laid eggs of *O. exvinacea* were oval, flat, creamish yellow in colour when laid singly. However, when laid in groups no proper shape was observed. Under field conditions, a series of observations revealed that the eggs were often laid into the well-established older webs. The eggs hatched within 3-4 days of egg laying in the early hours of photophase (4.30 to 7.30 AM).

Rao *et al.* (2020) reported that the egg-laying and egg-hatching time of the mango red banded caterpillar, *Deonalis sublimbalis* Snellen was observed in the early hours of photophase in the mango orchard. Similar results were found by Kavitha *et al*. (2005) in *O. exvinacea*. Patel *et al.* (2007) reported that webber moths of *O. euadrusalis* are preferred to lay eggs on the lower surface of the mango leaves singly as well as in clusters near the midrib, sometimes the eggs were also laid on the upper surface of leaves as well as on tender mango twigs. Beria *et al.* (2008) also reported the same in *O. euadrusalis.* Further, we observed that *O. exvinacea* moths preferred to lay eggs on infested mango plants than on healthy plants under field conditions. Under field conditions, a series of observations revealed that the moths laid eggs in already-established older webs. Wee (2016) observed that the diamondback moth, *P. xylostella* laid a greater number of eggs on larvae-infested cabbage plants than on intact uninfested cabbage plants. Similar reports were made by Ntiri *et al*. (2018) and Sokame *et al*. (2019) on stem borer, *Chilo partellus* Swinhoe on maize. Jayanthi *et al*. (2020) reported in detail about the oviposition behaviour of *O. exvinacea* in conspecific webs and observed the presence of eggs, multiple larval stages, and pupae that differ by many days within the same web that indicated the sequential oviposition behaviour of multiple gravid moths rather than oviposition by a single moth. Thus, during oviposition, *O. exvinacea* moths laid eggs near or in conspecific webs, demonstrating their social facilitation habit, indicating the existence of conspecifics can be an essential habitat selection cue for *O. exvinacea*.

Behaviour of neonate larvae

Under glasshouse conditions, detailed observations were made on the neonate larval behaviour on potted mango plants. The newly hatched larvae passed through seven instars by moulting six times. The neonates were often found to form a group on the under surface of the mango plant leaves and slowly initiated the scrapping of chlorophyll content. Larval feeding behaviour varied among the different larval instars; the larvae were found to be gregarious in the early instars as a group of larvae coalesced together and started scraping the chlorophyll content of the leaves and leaf webbing was found to be absent during this period. However, the middle and late larval instars (from third to fifth instars) initiated the leaf webbing and fed on the leaves along the edges leaving only the midrib and veins. During the sixth instar, larval feeding was found to be reduced comparatively and complete feeding cessation was noticed during the seventh instar and the grown-up larvae entered into the prepupal stage. The prepupa stayed concealed in old larval galleries which are made from frass and dried pellets of excreta and started spinning the cocoon with the help of silken threads secreted by their silk glands along with dried pellets of excreta and later moulted to form a strong pupal case. The site of pupation was observed in the web itself in both the glass-house as well as field conditions.

The time taken for the complete construction of the web ranged from 20-25 days almost coinciding with first-generation phenological stages from egg hatching to pupal formation. The mid-instar caterpillars (III to IV instars) were actively involved in making the web as they started secreting the silken threads in higher amounts as compared to early instar larvae (I and II instars). During the developmental period of larva, migration was also observed in the early photophase (5.00-7.30 am) as few larvae were moved to nearby leaves (especially II and III instars) and started feeding voraciously to form new web. The same behaviour was observed under the field conditions.

Butani (1979) reported that *O. exvinacea* caterpillars scrape the leaf surface in the early stages and subsequently web the tender shoots and leaves, with multiple caterpillars being found in a single web. Kannan and Rao (2006) observed that *O. exvinacea* caterpillars loosely web numerous shoot leaves together and feed by defoliating from within. Haseeb *et al*. (2000) also reported that the larvae of *O. euadrusalis* start scraping the leaves after hatching and forming webs by feeding voraciously in later stages. Patel *et al.* (2007) reported that caterpillars scrape the leaf surface for chlorophyll initially and web the leaves by feeding on edges to the midrib, leaving a network of veins behind. The site of pupation was observed in the web itself in both the glasshouse and also in the field conditions. Mallikarjuna (2019) reported similar results as they studied the detailed biology of *O. exvinacea* in both laboratory and field conditions. Similar behaviour was reported by many researchers (Sajitha and Gokuldas, 2015; Gundappa *et al*., 2016; Kasar *et al*., 2017; Kerketta *et al*., 2021).

Mating behavioural profiles

During the scotophase period, the moths were found to be very active and exhibited a series of behavioural events compared to photophase. The detailed mating behaviour inventory revealed major behaviours *viz.,* resting period (R), swift antennal movements(SAM), walking with antennal swift movement (WK), flight and fluttering of the wings (FL), mate tracking (MT), mate approaching (MA) and mating (M) in both male and female moths. Among the series of events, most of the time both sexes exhibited swift antennal movement (SAM) (326.33±26.28 min) followed by a resting period (300.67±22.68 min) and mating (68.67±7.45 min). Further, both sexes walked along together showing SAM (53.34±8.90min) and resorted to flight mode with often fluttering of the wings and SAM (38.67±9.18min). Both sexes approached each other (12.00±1.80 min) and tracked each other (8.67±2.35). However, the peak time of resting was recorded during the period from 6.00 PM to 8.30 PM and 4.30 AM to 6.00 AM. Both sexes walked with SAM majorly between 9.30 PM to 10.30 PM and 2.00 AM to 2.30 AM. Intermittent flight and wing fluttering with SAM were often noticed between 11.00 PM to 12.30 PM. Both male and female moths tracked each other during the late scotophase *i.e.,* from 1.00 AM to 2.00 AM and approached each other between 2.00 AM to 3.00 AM. The mating period was observed between 3.00 AM to 4.30 AM (Fig.1). Interestingly, throughout the scotophase (8.00 PM to 5.00 AM) moths continuously exhibited swift antennal movements which were totally absent during the photophase. Further, a compilation of transition behavioural frequencies (Table 1a) and transition behavioural rates (Table 1b) (as per Markov first order) revealed that more behavioural transitions were noticed between the resting period and SAM in both sexes (αR,SAM= 0.57; αSAM,R= 0.48). Similar transitions were also observed among the behaviours namely mate approaching and SAM in both the sexes (αMA,SAM= 0.31; αSAM,MA= 0.12), followed by SAM (in both sexes) to walking with SAM (in both sexes, αSAM, WK= 0.13; αWK,SAM= 0.37), followed by mate tracking and SAM (αMT,SAM= 0.08; αSAM,MT= 0.06), flight and wing fluttering and SAM (in both sexes, αFL,SAM= 0.45; αSAM,FL=0.10).

Further, moths often walked followed by and resting period (in both sexes, αWK,R= 0.28; αR,WK=0.24). Moreover, transitions were also observed between the flight and fluttering of the wings and resting period (αFL,R= 0.32; αR,FL = 0.18), mate approaching and walking with antennal swift movement (αMA,WK= 0.00; αWK,MA =0.05), walking with antennal swift movement followed by flight and fluttering of the wings (αWK,FL= 0.13; αFL,WK = 0.15), mate approaching and mate tracking (αMA,MT= 0.00; αMT,MA = 0.50), mate tracking and flight and fluttering of the wings (αMT,FL= 0.00; αFL,MT= 0.07).

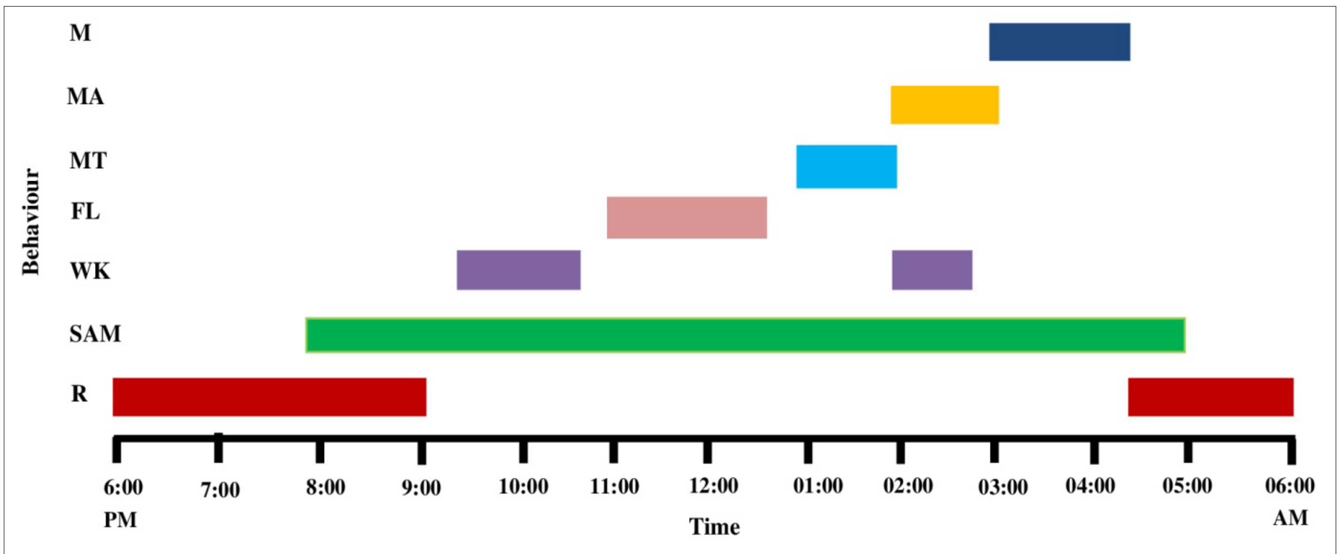

Fig.1. Behavioural dynamics of the adult mango leaf webber, *O. exvinacea* moths during scotophase

(R = Resting, SAM = Swift antennal movement, WK = Walking with antennal swift movement, FL = Flight and fluttering of the wings, MT = Mate tracking, MA = Mate approaching and M = Mating).

However zero transition was also found between resting period and mate approaching (αR,MA,= 0.00; αMA,R= 0.00), mating approach and flight and fluttering of the wings (αMA,FL= 0.00;αFL,MA= 0.00), mating and walking with antennal swift movement (αM,WK= 0.00; αWK,M= 0.00), mating and flight and fluttering of the wings (αM,FL= 0.00; αFL,M= 0.00) and mating and mate tracking (αM,MT= 0.00; αMT,M= 0.00) (Fig. 2).

Similarly, the calculated behavioural transition rates (%) also revealed that the major behaviour transitions were MA to M (68.57%) followed by M to R (58.82%), R to SAM (57.33%), MT to MA (50.00%), SAM to R (48.48%), FL to SAM (45.00%), M to SAM (41.18%), WK to SAM (36.84%), FL to R (32.50%), MA to SAM (31.43%), WK to R (28.95%), R to WK (24.00%), MT to WK (22.22%), MT to R (19.45%), R to FL (18.67%)

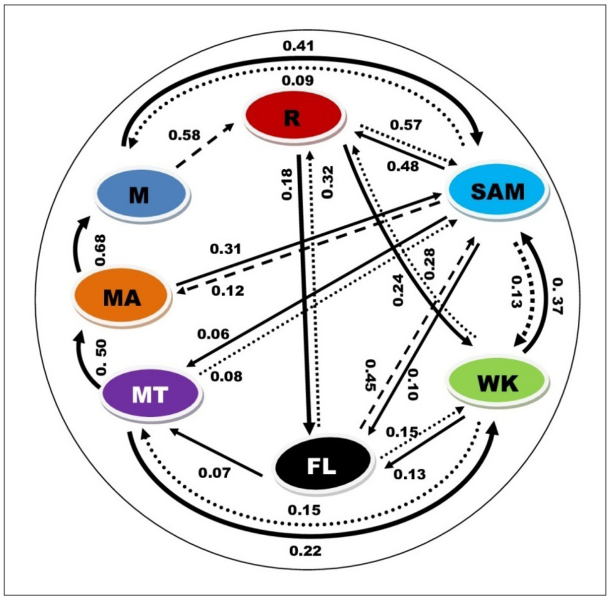

Fig.2. Markov state space diagram of the mating behaviour transitions in mango leaf webber, *O. exvinacea.*

(R = Resting, SAM = Swift antennal movement, WK = Walking with antennal swift movement, FL = Flight and fluttering of the wings, MT = Mate tracking, MA = Mate approaching and M = Mating).

Table1. Transition matrix of the behaviour of *O. exvinacea* based on first order markov model

a. Behaviour transition frequencies

	R	SAM	WK	FL	MT	MA	M	Total
R	-	43	18	14	0	0	0	75
SAM	32	-	9	7	4	8	6	66
WK	11	14	-	5	6	2	0	38
FL	13	18	6	-	3	0	0	40
MT	7	3	8	0	-	18	0	36
MA	0	11	0	0	0	-	24	35
M	30	21	0	0	0	0	-	51
Total	93	110	41	26	13	28	30	349

b. Behaviour transition rates

	R	SAM	WK	FL	MT	MA	M
R	-	α R,SAM =0.57	α R,WK =0.24	α R,FL =0.18	α R,MT =0.00	α R,MA =0.00	α R,M =0.00
SAM	α SAM,R =0.48	-	α SAM,WK =0.13	α SAM,FL =0.10	α SAM,MT =0.06	α SAM,MA =0.12	α SAM,M =0.09
WK	α WK,R =0.28	α WK,SAM =0.37	-	α WK,FL =0.13	α WK,MT =0.15	α WK,MA =0.05	α WK,M =0.00
FL	α FL,R =0.32	α FL,SAM =0.45	α FL,WK =0.15	-	α FL,MT =0.07	α FL,MA =0.00	α FL,M =0.00
MT	α MT,R =0.19	α MT,SAM =0.08	α MT,WK =0.22	α MT,FL =0.00	-	α MT,MA =0.50	α MT,M =0.00
MA	α MA,R =0.00	α MA,SAM =0.31	α MA,WK =0.00	α MA,FL =0.00	α MA,MT =0.00	-	α MA,M =0.68
M	α M,R =0.58	α M,SAM =0.41	α M,WK =0.00	α M,FL =0.00	α M,MT =0.00	α M,MA =0.00	

c. Per cent of behaviour transitions

	R	SAM	WK	FL	MT	MA	M	Total
R	-	57.33	24.00	18.67	0.00	0.00	0.00	100.00
SAM	48.48	-	13.63	10.60	6.06	12.12	9.10	100.00
WK	28.95	36.84	-	13.16	15.79	5.26	0.00	100.00
FL	32.50	45.00	15.00	-	7.50	0	0	100.00
MT	19.45	8.33	22.22	0	-	50.00	0	100.00
MA	0	31.43	0	0	0	-	68.57	100.00
M	58.82	41.18	0	0	0	0	-	100.00
Total	188.2	220.11	74.85	42.43	29.35	67.38	77.67	

WK to MT (15.79%), FL to WK (15.00%), SAM to WK (13.63%), WK to FL (13.16%), SAM to MA (12.12%), SAM to FL (10.60%), SAM to M (9.10%), MT to SAM (8.33%), FL to MT (7.50%), SAM to MT (6.06%) and WK to MA (5.26%) (Table 1c).

A similar experiment was carried out by Rao *et al.* (2020) in mango red banded caterpillar, *D. sublimbalis* under laboratory conditions. The results revealed that major behavioural transitions were observed between 6.00 PM to 6.00 AM in *D. sublimbalis* as swift antennal movement (SAM) (493.45±37.32 min) followed by resting period (179.5±20.48 min), walking along with SAM (77.93±12.17 min), resorted to flight with often fluttering of the wings and SAM (51.72±10.78 min), approaching each other (10.68±3.26 min) and tracked each other (5.17±2.30). Kelley (2016) observed the mating behaviour of odd beetle, *Thylodrias contractus* Motschulsky in order to investigate the biosynthesis of sex pheromones. Agee and Webb (1969) recorded the mating behaviour of bollworm, *Helicoverpa zea* Boddie under laboratory conditions. Haynes and Birch, 1984 reported that the mating behaviour of the artichoke plume moth, *Platyptilia carduidactyla* Riley has shown a series of behavioural events such as wing fanning, flying, flying upwind, landing, wing fluttering while walking, approaching the female, rapidly fluttering the wings towards the female and making a copulatory attempt.

Intraspecific competition

In the present study, larval competition and migration in *O. exvinacea* were investigated under field conditions. A total of 25 webs were selected randomly in the mango orchard to observe larval competition and migration in *O. exvinacea.* During the observations each web was observed slowly without disturbing much with the help of a magnified hand lens. Interestingly, we found different instars (first to seventh instar) in a single web. A series of different behavioural dynamics were observed throughout the observation period. The larvae moved out from the web and at the same time, some larvae were found entering into the webs from nearby webs. This observation clearly indicates that there is competition between the larval populations within the web. This competition may be due to a shortage of food or space. We have also observed the migration behaviour of larvae to nearby webs. There is no relevant research available, particularly on *O. exvinacea,* regarding intraspecific competition among brood members. Rao *et al*. (2020) reported that few larvae go to nearby fruits in the early morning hours as part of their migration behaviour which is observed in mango red banded caterpillar, *D. sublimbalis.*

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